F-15 Intelligent Flight Control System and Aeronautics Research at NASA Dryden

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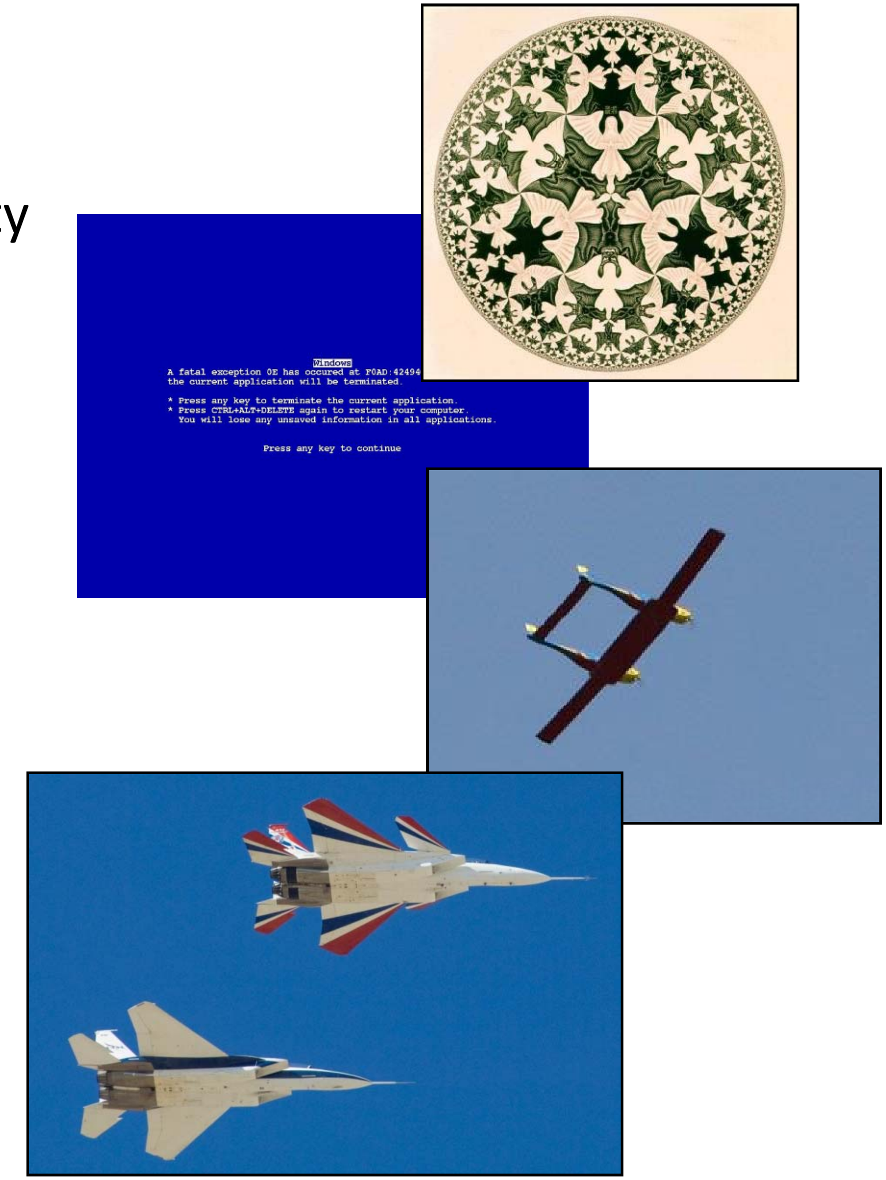
Presented to students at Cal Poly Pomona, 30 April 2009

Purpose

- Give you information that helps you choose your career
  - Advertise my research center
  - Engineering: research is different from development
  - Example Project: Intelligent Flight Control System

Personal Background

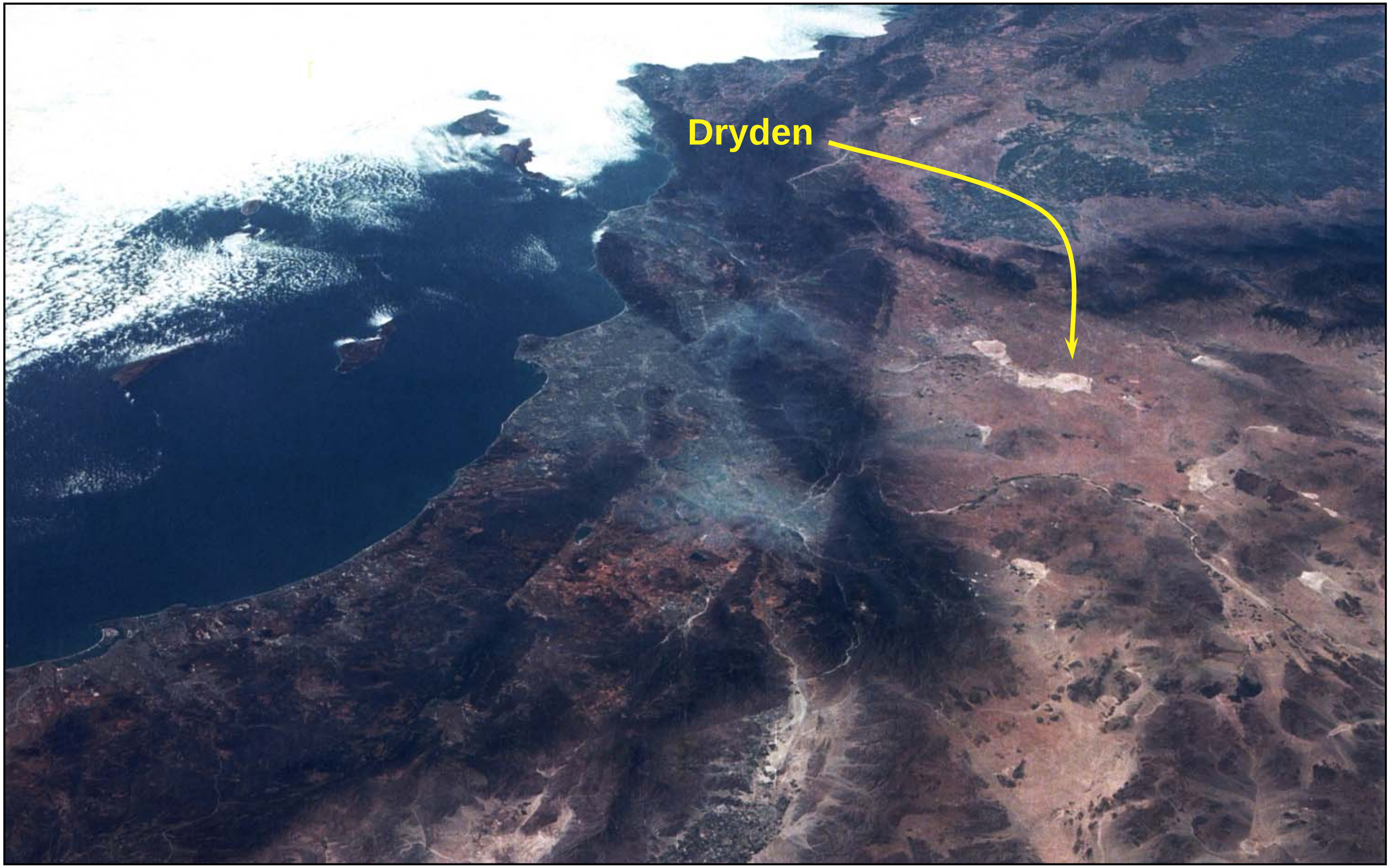
- B.A. Mathematics
  University of Missouri, Kansas City
- Six years in I/T
- M.S. Aerospace Engineering
  University of Kansas
  (Controls, UAV research)
- Two years at NASA Dryden
  (Flight controls research)

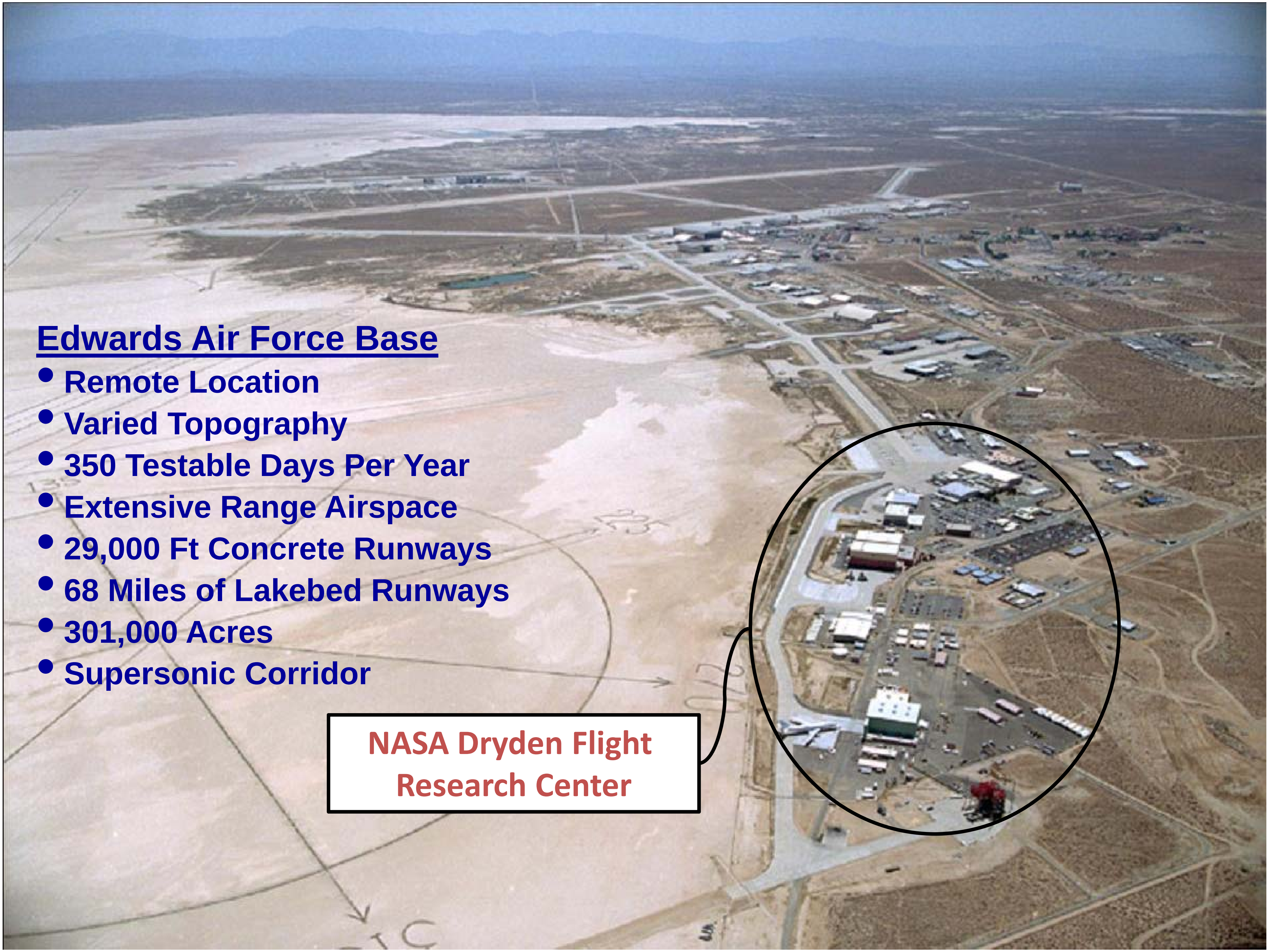


Dryden Flight Research Center

To Fly What Others Only Imagine

Dryden as Seen from Space





Edwards Air Force Base

- Remote Location
- Varied Topography
- 350 Testable Days Per Year
- Extensive Range Airspace
- 29,000 Ft Concrete Runways
- 68 Miles of Lakebed Runways
- 301,000 Acres
- Supersonic Corridor

NASA Dryden Flight Research Center

Dryden Flight Research Center

Advancing Technology and Science Through Flight

Mission Elements

- Perform flight research and technology integration to revolutionize aviation and pioneer aerospace technology
- Validate space exploration concepts
- Conduct world-wide airborne science operations
- Support operations of the Space Shuttle and the ISS

… for NASA and the Nation

Why?

The NASA Dryden Flight Research Center was named after Dr. Hugh L. Dryden, the first Deputy Administrator of NASA. The following is his explanation as to why there is a need for flight research,

"... to separate the real from the imagined and to make known the overlooked and the unexpected. . .".

NASA Aeronautics

Autonomous Aerial Refueling Demonstration

X-48B Blended Wing Body

F-15B Quiet Spike

NF-15 Intelligent Flight Controls

Aeronautics Disciplines

- Dryden research engineering teams are multidisciplinary:

  Structures, Aerodynamics, Propulsion, Systems, Instrumentation, and Controls

- Many other branches support flight test:

  Operations, Simulation, Maintenance, etc.

For today's example, the focus is on controls research…

F-15 IFCS PROJECT

Intelligent Flight Control System (IFCS)

Airplanes Get Damaged

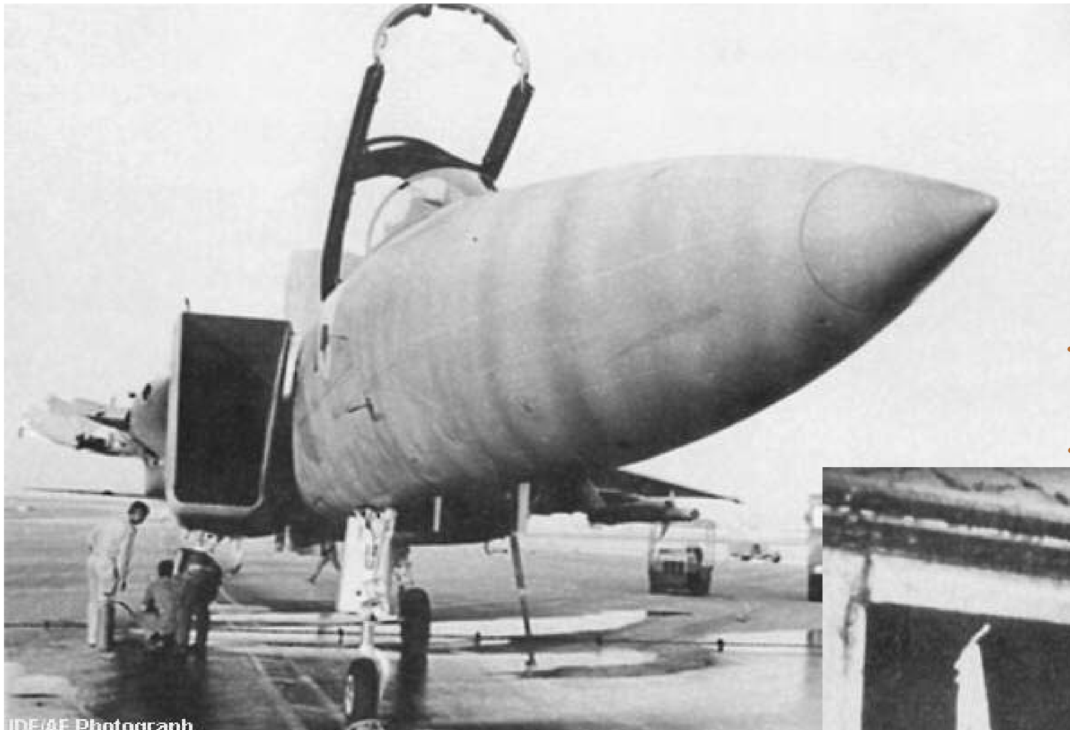
- Collisions
- Bird Strikes
- Mechanical Failures
- Battle Damage

… and other causes

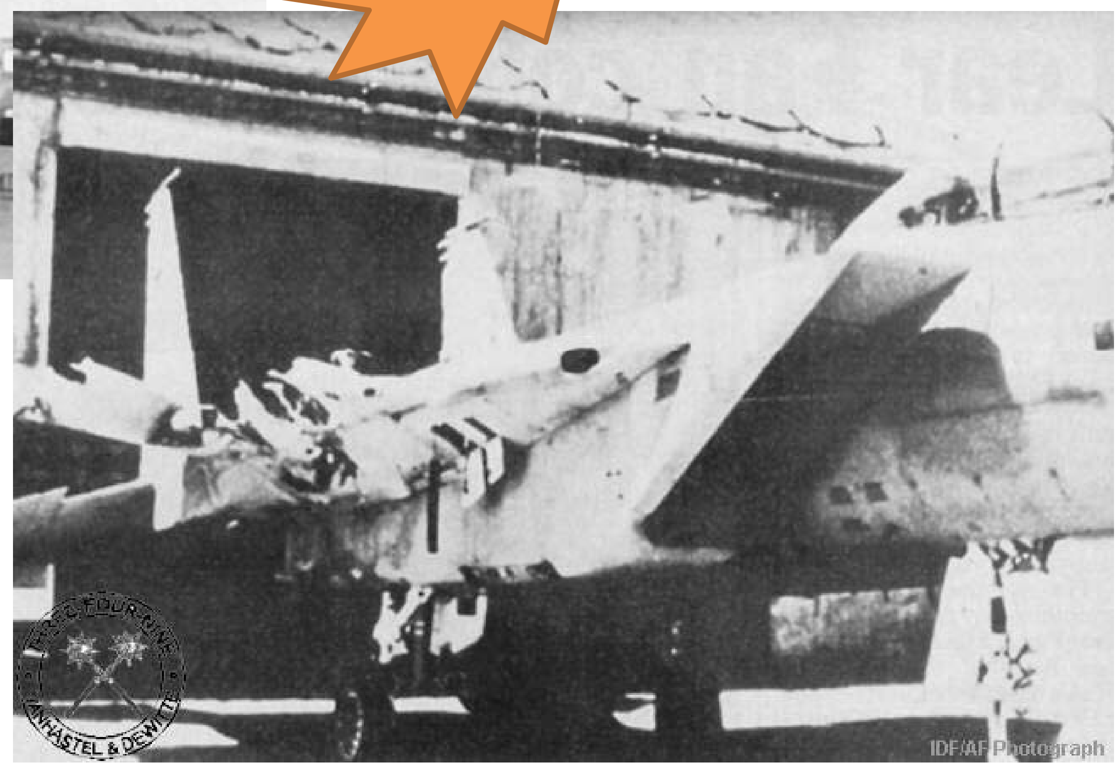
Think about hitting a 10 lb bird at 500 mph!

In some cases, heroic pilots have been able to land airplanes with major damage…

Israeli F-15 Mid-Air Collision



Amazing pilot skills!



F/A-18 Mid-Air Collision

WOW!

F-15 IFCS Project Goals

- Adapt to damage
- Stabilize the damaged airplane
- Restore handling qualities

Hopefully the control system can help even average pilots save the day.

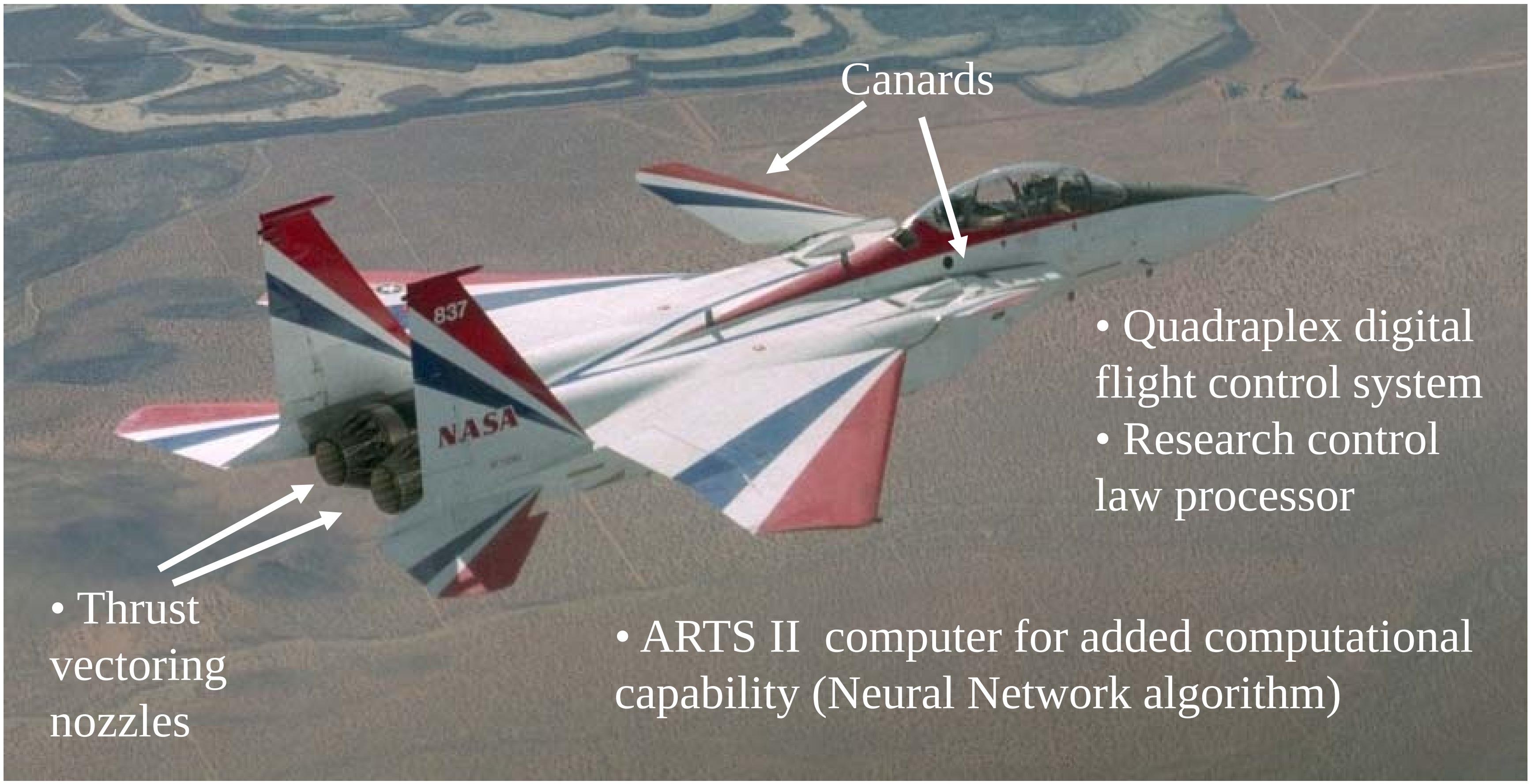
The Experiment

- Simulate a damaged airplane in flight:
  - Lock a control surface
  - Destabilize the airplane
- Turn on the IFCS, let it learn

- Give the pilot a task:
  - Fly in formation
  - Track a target
- Compare the results to flying without IFCS

The Laboratory

Extensively modified F-15:



NASA NF-15B Tail Number 837

Control Surface "Failure"

[video]

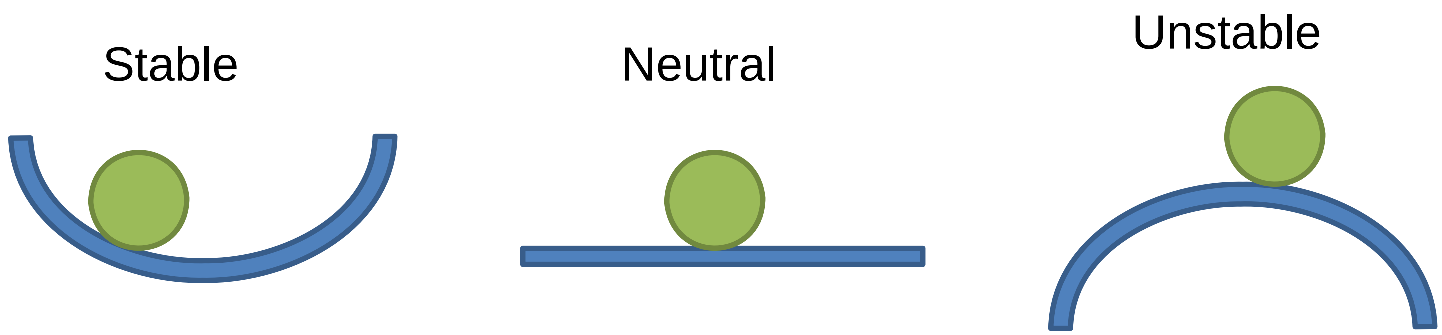
- Freeze the left stabilator
  - Reduces pitch authority
  - Causes cross-coupling

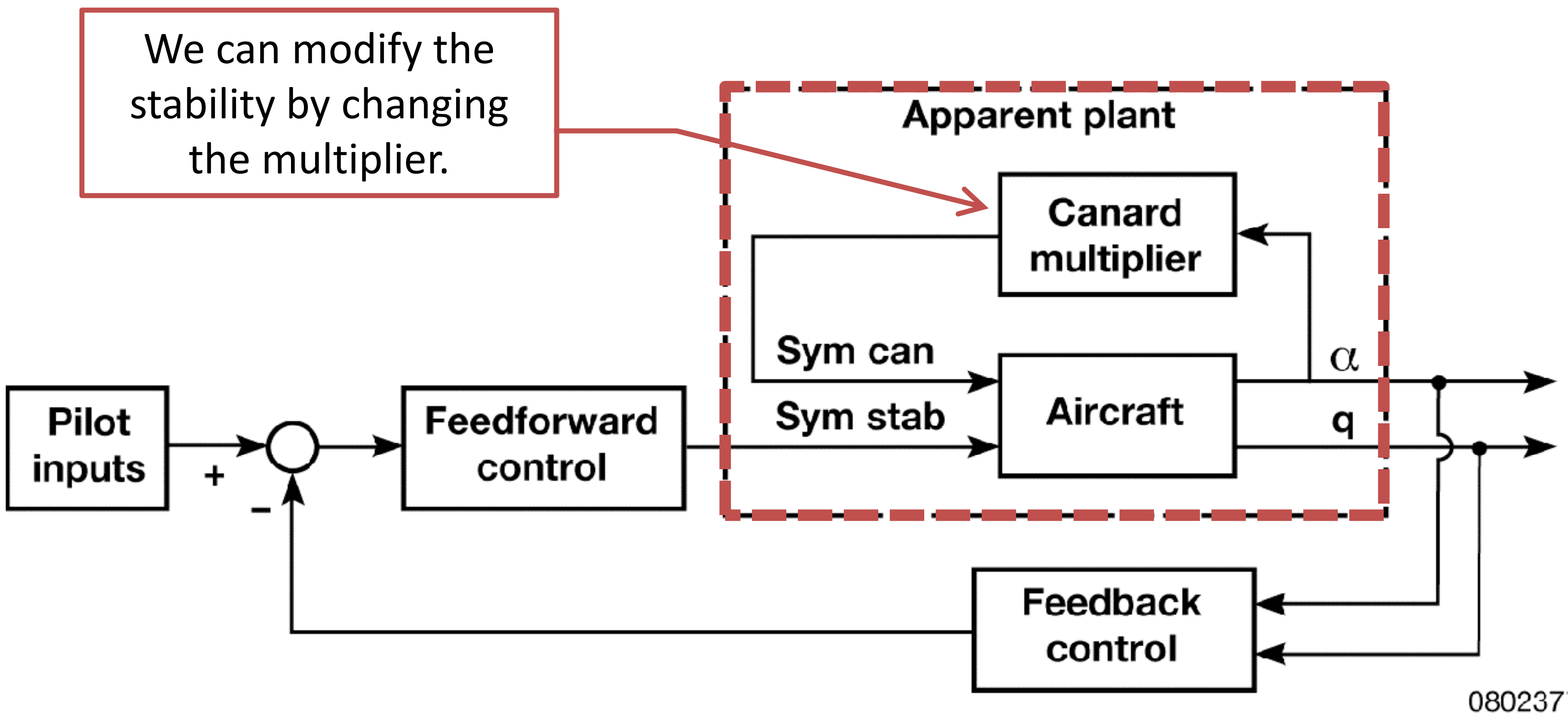
    (pitch input causes roll!)

Analogy:

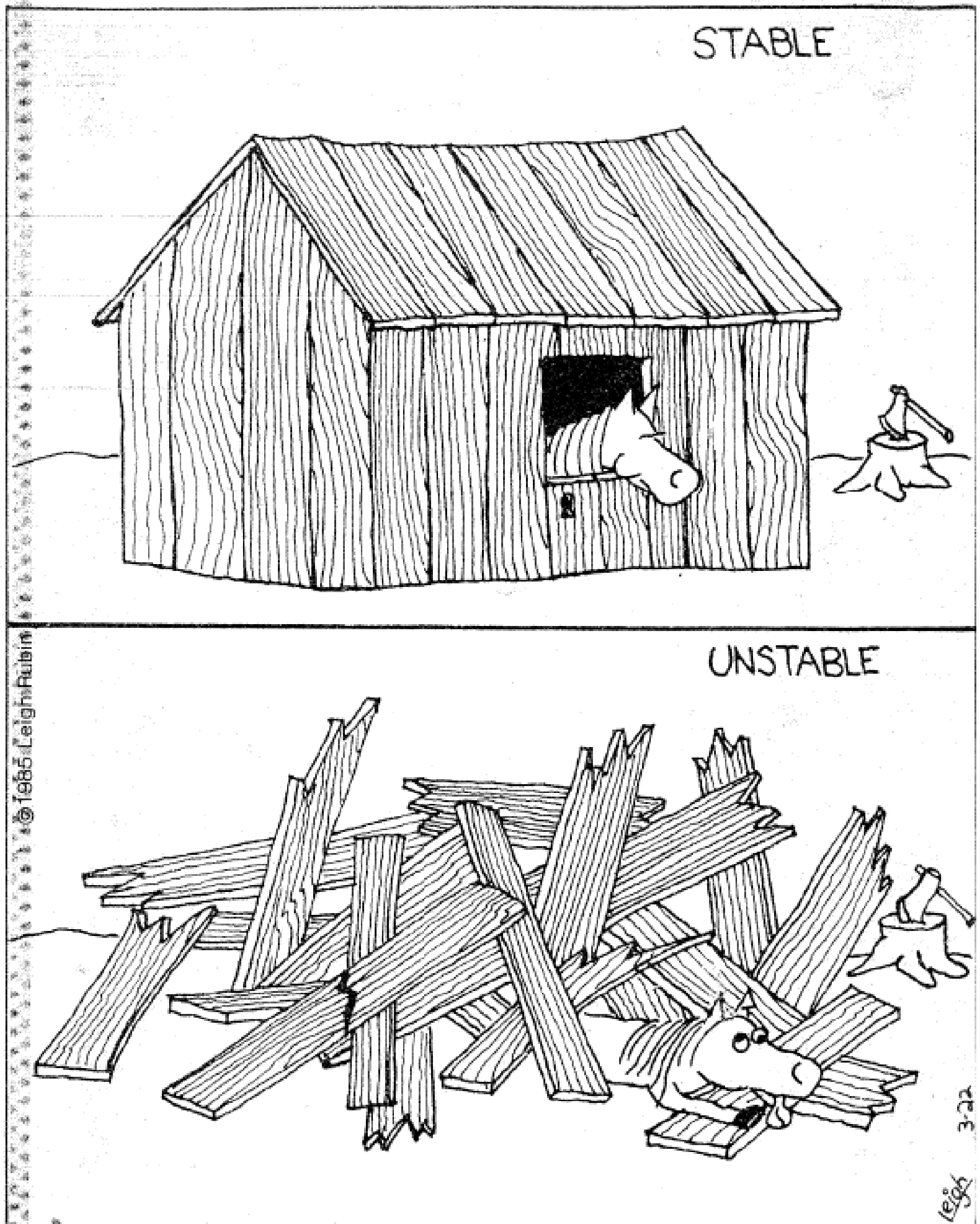
Turn your computer's mouse sideways.

Longitudinally Destabilized Airplane

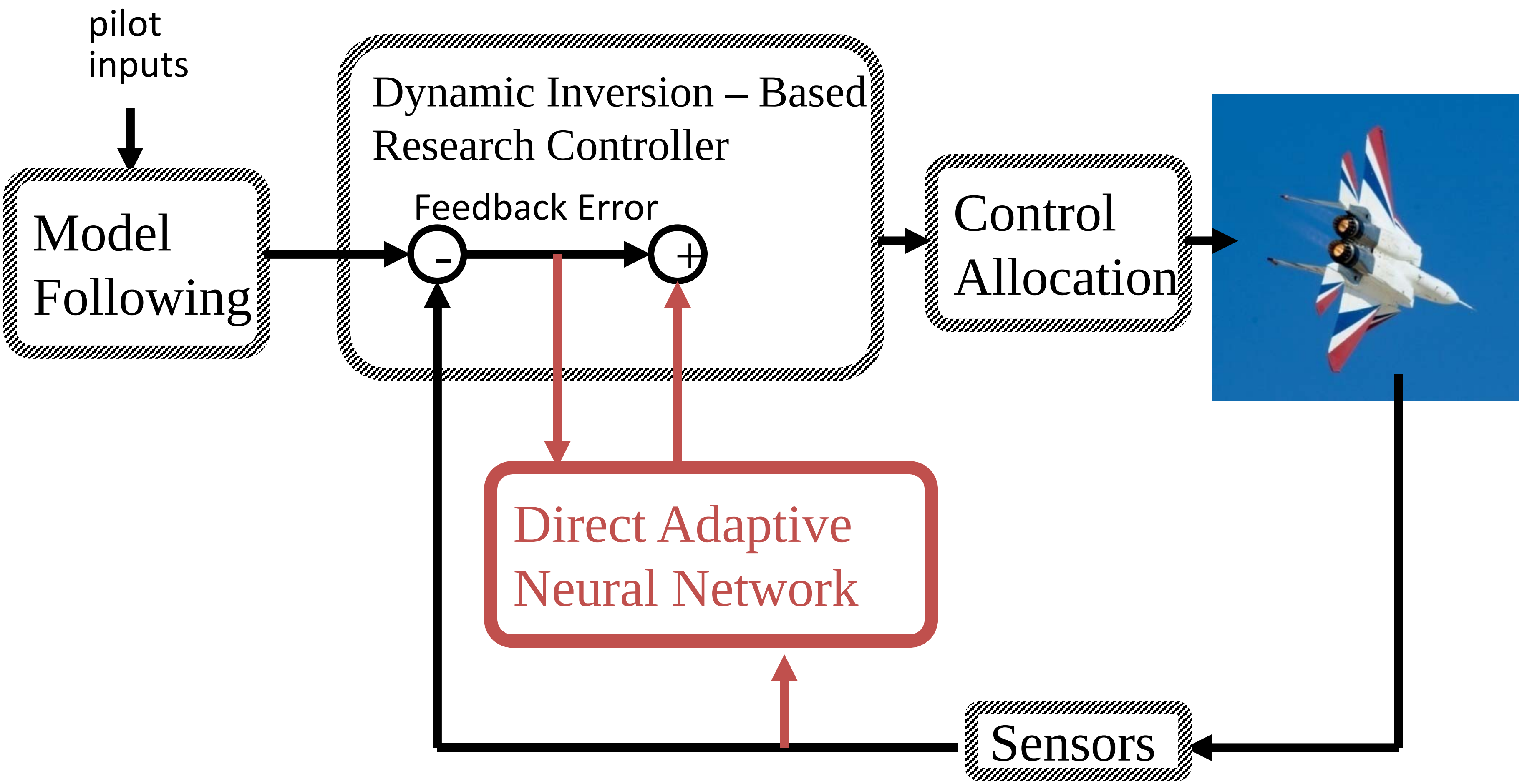




Rubes® By Leigh Rubin



Direct Adaptive Control Architecture



Desired Adaptation Response to Failure

- Regain stable platform
- Re-establish good handling qualities
- Provide ability to safely land airplane
  - Stay within maneuver constraints
  - Respect structural limitations

Research Engineering Workflow

Design

- MATLAB / Simulink
- Marker Board

Sim

- Engineers' Evaluations
- Pilots' Evaluations

Flight

- Staff Mission Control Room
- Monitor Telemetry

Analysis

- MATLAB
- Write Reports

Nonlinear 6-DoF Simulation

- Fix-based engineering simulations
- Cockpit Interface Unit
- Simulation Electric Stick
- Used for pilot evaluations
- Operable by one person
- Interfacing with flight hardware is routine

[video]

Flight Test

- F-15
  - Test Pilot
  - Flight Test Engineer
- F-18 chase
  - Pilot
  - Videographer
- Mission Control Room
  - Flight Director
  - Engineers from all disciplines
    (controls, aero, propulsion, structures, systems, instrumentation)
- Maintenance & Support

[video]

IFCS Remarks

- The simulated failure challenged the adaptive system
- Adaptive algorithm generally followed simulation prediction
  - The adaptation moved in direction to correct for simulated failure
  - Real world disturbances and noise did not adversely affect learning
- Adaptation significantly improved performance
  - Re-established good stability margins
  - Aircraft began to respond similarly to the non-failure case
- Continued training demonstrated convergence issues

- Gained valuable real world experience that has already pushed technology to more acceptable level

Benefits of Full-Scale Flight Test

- Full scale flight test forces designers to address real-world issues
- Provides high-visibility demonstration
- Adds credibility that adaptation technology can be a viable design option

- Helps to "separate the real from the imagined"

Questions?